Space Weather Technical Forecast

Issued on Tuesday, 21 February 2023 at 12:43 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Minor/Moderate R1/R2 radio blackouts Likely.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate in the past 24 hours, as recorded at GOES16, with an M-class flare at 20/1458UTC reaching M4.4 from AR3234. This group also produced a doublet of high-end C-class flares around twelve hours later, and a several-stage eventual M4.7 at 21/1123UTC to make it the most notable region on the disc. This group is currently near the northeastern limb which is precluding proper analysis, however it appears to be at least an Eki/Beta, with rapid areal growth in its trailing spots.

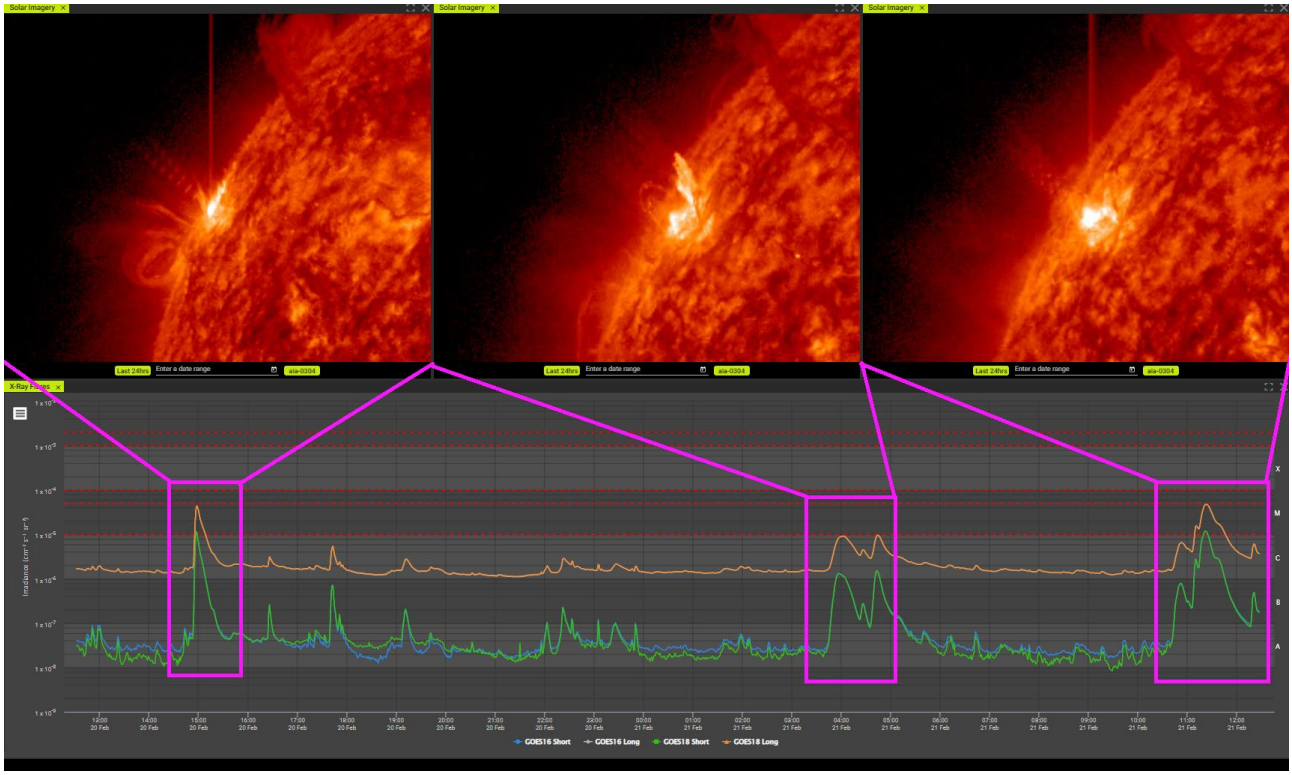

Figure 0: AIA304 and GOES X-ray traces for the most notable flares from AR3234 in the past 24 hours. Many of these flares have also produced non-Earth directed CMEs.

The above was one of seven numbered regions on the disc at present. Most of these were either stable and unipolar or else in decay, including the X2.2-producing AR3229 (on 17 February), which has seen its delta spot fade as well as an overall areal decline.

A few Coronal Mass Ejections (CMEs) were visible in available coronagraph imagery for the period. The first of these was narrow and east-directed, likely being associated with the aforementioned M4.4 flare. This signal was then polluted by a brighter and wider-angled release

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from the northeastern far side later in the UTC evening. A front-sided northwestern CME visible on Lasco C2 heading largely northwest was tentatively traced back to activity high in the corona in AIA171 (near the edge of the field of view) around the turn of the UTC day. This CME has been analysed but modelling results are pending - any effect from this is likely to be minor and related to the shock only - later this working week. This will be confirmed when results become available. The final event was a large, fast southeastern far-sided CME seen on STEREO A COR2 at the time of writing, to no effect at Earth. All considered, the northwest-directed event is the only one considered to have any possible minor Earth-directed component, to be confirmed.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR at L1, were indicative of ongoing CME influence from the 17 February X2.2-tied event, which arrived at Earth 20/1045UTC to muted effect. The low energy proton increases observed at ACE EPAM LEMS have shown a reduction in some energies in recent hours, perhaps indicating that a waning tendency to a slow wind is in course, i.e. without fully going into the CME's magnetic cloud.

The solar wind speed has been mostly Slightly Elevated in the period, with a slight decrease observed with time in a envelope spanning 400-475km/s. The solar wind density has shown a similar slight decrease: from Slightly Elevated levels in the teens of ppcc to more typical single figures by the period's end. The IMF has been Slightly Elevated and erratic in character, peaking both to start and end the 24 hours near 15nT. The north-south component was mainly erratic about being neutrally-orientated, but gradually transitioned to become mainly anti-aligned with the Earth's field later in the period, with limits of +7 and -12nT. The phi angle was mainly away from the Sun (positive), but again with some deviation observed.

The net result of the above solar wind measures has been provisionally Quiet to Unsettled despite the CME, with a late peak of Kp '3+' seen in the 00-03UTC and 09-12UTC intervals.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES16 remained at Background levels.

High energy electron flux (greater than 2MeV) at GOES16 ranged between Moderate and Normal Background levels, with a diurnal peak near 500pfu late in the UTC afternoon of Monday 20 February. The associated 24-hour electron fluence has been well below the Active (1e8 integrated pfu) threshold, with a step-wise rising tendency to reach 7.68e6 integrated pfu at 21/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate solar activity is Likely, with the presence of both the X2.2-producing AR3229 and now a new potent and growing region AR3234 in the northeast. Both of these dominant groups should be present throughout the four days.

Solar Wind / Geomagnetic Activity: There is one low confidence CME in the forecast - that which left the southwest quadrant on 19 February, although any influence should be from the shock only and even this is low confidence, passing 1AU later Wednesday 22 or into Thursday 23 February (UTC). There is now also one other candidate from the northwest quadrant undergoing modelling - with results to be confirmed.

The above excepted, Earth should see a slow regime transition to a fast one in CH77's high speed stream during the UTC morning of day two, Wednesday 22 February, giving a peak Slight Chance of G1 for the four-day period, reducing with time to largely Quiet conditions by the end of the current UTC week (with moderate confidence given the possibilities of CME shocks).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is most likely to remain at Background levels, but with a slowly increasing Slight Chance of rising towards the S1 level, perhaps exceeding it, should any suitable larger flares occur.

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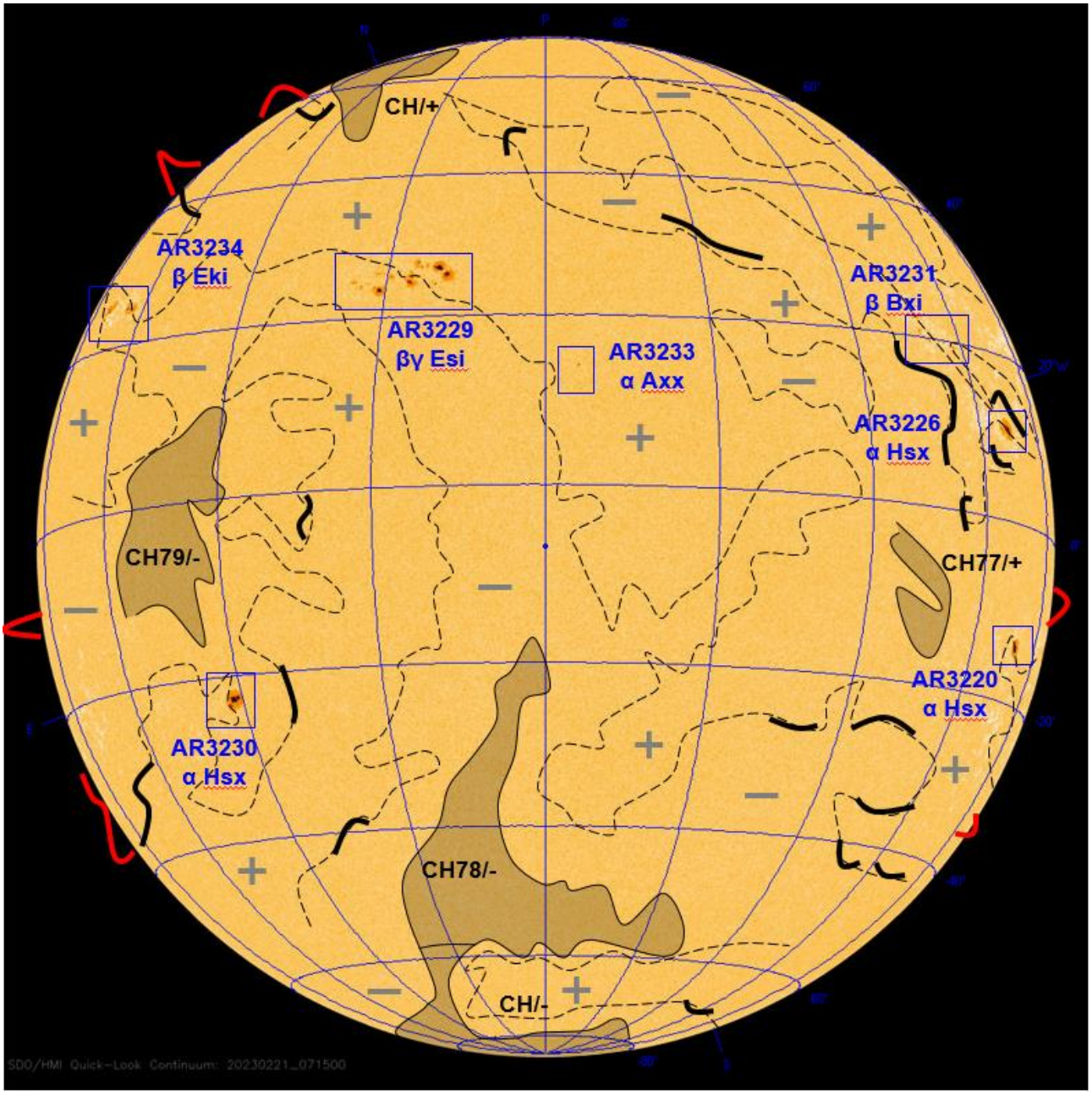
High energy (greater than 2 MeV) electron flux may increase later in the forecast period in response to the fast wind enhancement, however this is low confidence. The associated 24-hour fluence is expected to remain below the Active threshold (1e8 integrated pfu).

Figure 1. Solar Analysis Valid 21/0715UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There is one low confidence CME in the forecast - that which left the southwest quadrant as a prominence eruption on 19 February, although any influence should be from the shock only and even this is low confidence, passing 1AU later Wednesday 22 or into Thursday 23 February (UTC). There is now also one other candidate from the northwest quadrant undergoing modelling - results to be confirmed.

The above excepted, Earth should see a slow regime transition to a fast one in CH77's high speed stream during the UTC morning of day two, Wednesday 22 February. STEREO A PLASTIC measurements perhaps suggest a fast wind may have arrived as of 21/0700UTC, although there are data gaps and CME pollution to contend with that lower confidence in this identification. Should this be the cause, CH77 can be expected to arrive around UTC dawn on day two, Wednesday 22 February to give a peak Slight Chance of G1 for the four-day period. This should then reduce with time to largely Quiet conditions by the end of the current UTC week (with moderate confidence given the possibilities of CME shocks).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	20	5	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
19/2320	Partial	Prominence near AR3217	SW limb	662km/s	Probable miss	Some Enlil ensemble members suggest glance late 22 into 23 February.

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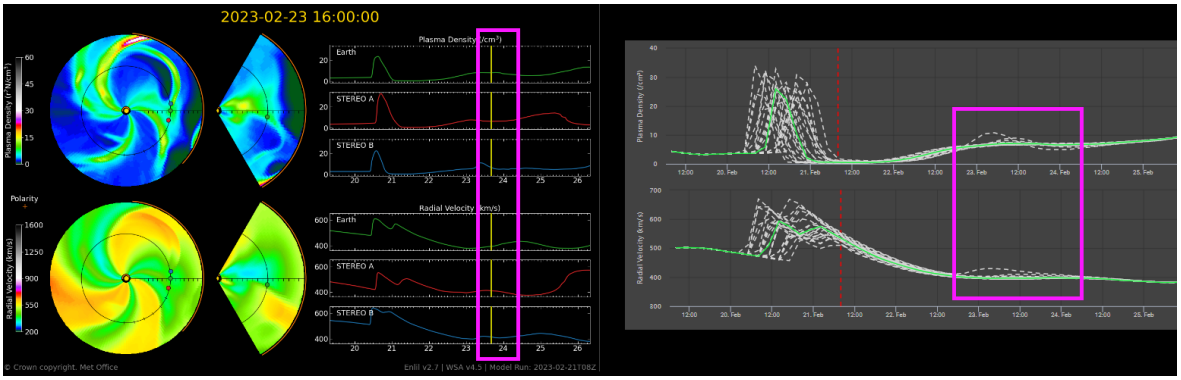
Figure 2: 21/0800UTC MOSWOC Enlil run and ensemble, which persists in a minority of members showing a glancing blow from the shock associated with the 19 February southwest quadrant prominence CME. The most likely forecast remains a miss.



Radio Blackouts - X-Ray Flares:

Isolated M-class X-ray flares are Likely in the four-day period, with a Slight Chance of rising again to High with further X-flares - the main risk being from AR3234 and perhaps still AR3229 in the northeast.

Most of the current sunspot regions are either stable and unipolar or else in decay, including the X2.2-producing AR3229 (on 17 February), which has seen its delta spot fade away as well as an overall areal decline and tendency towards smaller and more symmetrical penumbrae. New region AR3234 is now potentially the most notable on the disc, with Eki/Beta complexity at least and a rapid growth trend in its trailing group, perhaps hiding Mt Wilson delta or gamma complexity by inference from its activity.

Both of the above main regions should occupy the Earth-facing side through the next week, and barring development they should account for the bulk of the risk of significant flares. This is the posited rationale for only a slight decrease in risk with the departure of many of the western limb sunspot groups around midweek, which are for the most part unipolar or simple dipoles.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**R1-R2 M Class**	Yes	60	60	50	50
Very Active	**R3 to R5 X Class**	No	10	10	10	10

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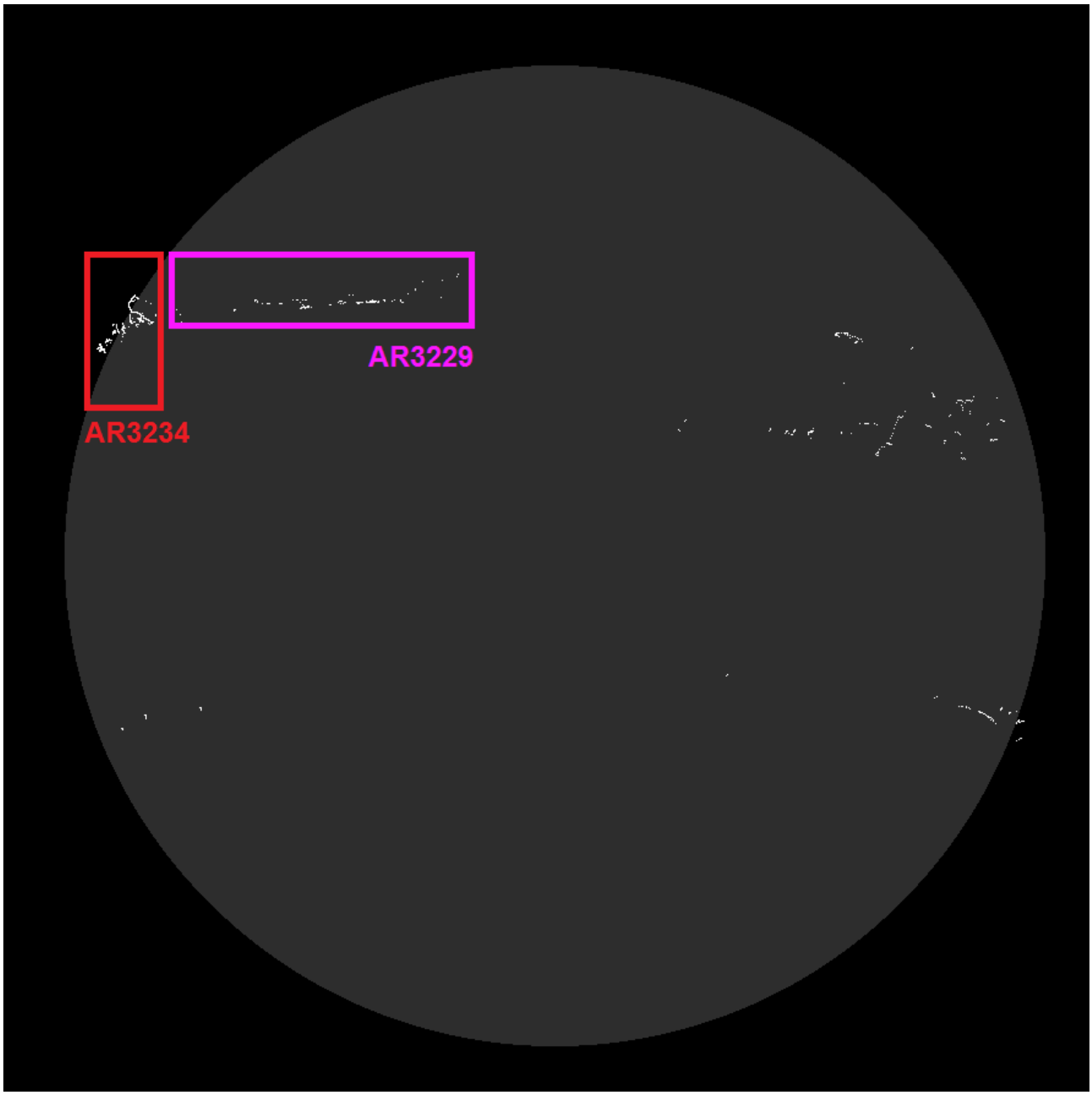
Figure 3: Past four days X-ray flare sources above C-class, i.e. since the X2.2 on 17 February, with most of these attributable to AR3229 and AR3234, and with all of the larger events tied to these two regions (not shown). Image courtesy of SIDC ROB.



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Solar Radiation Storms - (High Energy Protons):

High energy (greater than 10MeV) proton flux, as observed by GOES16, is currently at Background levels.

While there have been no notable enhancements to the high energy proton spectrum in the past UTC week, this is perhaps largekly because the larger X-ray events have been limited to the eastern solar hemisphere. Ar3229 and AR3234's westward progress should offer a very gradually increasing Slight Chance of reaching S1 or above as they rotate into a more favourable position should they flare appropriately.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed at GOES16 is currently showing a very slight day-on-day increase to oscillate between Moderate and Normal Background levels.

Any more persistent increase in flux is now likely to be suppressed by geomagnetic activity arising from the fading 17 February CME at Earth. In terms of the forecast, there are now some signals that something resembling CH77 may have arrived at STEREO A (a day upwind in the Parker spiral), although the speed trace is erratic and has yet to settle, which makes gauging the intensity of CH77 difficult. It is still therefore considered relatively unlikely that CH77 should prove capable of Active electron fluence later this working week (UTC).

With remaining transients now low confidence for affecting Earth at all, and with CH77 a persistent feature, confidence in MOSWOC REFM output is increasing, and this persists in maintaining below-Active fluence.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	10	20	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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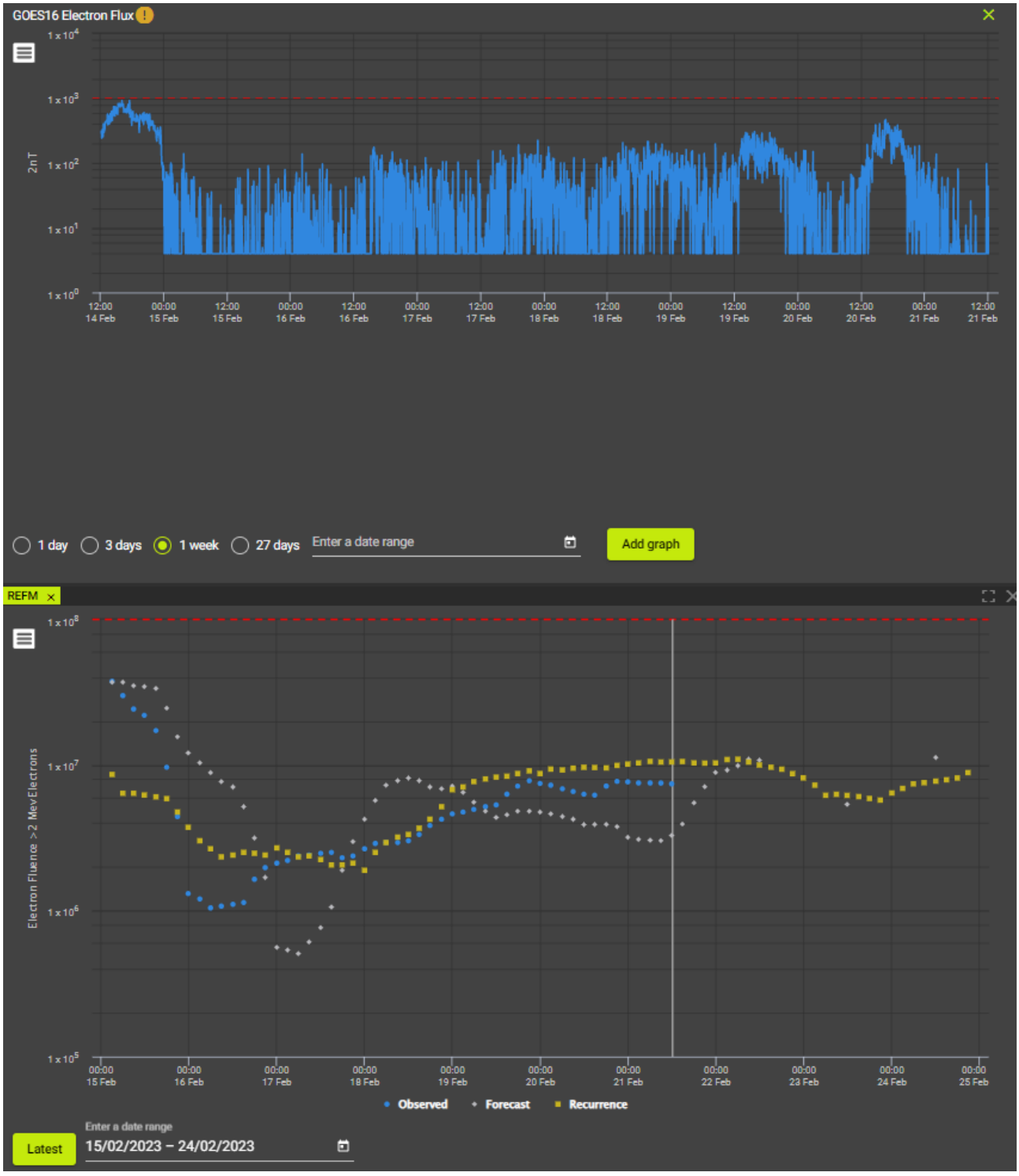
Figure 4: Top: past week in GOES16 high energy electron flux (greater than 2MeV); bottom: past week's 24-hour integrated fluence observations, also showing REFM predictions and persistence. The three-day forecast is likely to be good guidance in the expected absence of any CME activity, which is the preferred scenario (with one from the northwest on the morning of 21 February pending).



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